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A Spatiotemporal Analysis of Duhok's Urban Growth (2010–2025): A Narrative Review of the Duhok Master Plan

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1 ABSTRACT

Duhok in the Kurdistan Region of Iraq has seen an expansion rapidly. The growth is so rapid that we think it goes against the planned development of the area. The Vossing Report's urban master plan is to be a guide for development until 2023. This narrative review will assess the effectiveness of the urban growth of Duhok governorate in the Iraqi Kurdistan Region. The main goal of this study is to show the current state of Duhok urban development. This study focuses on the different land use areas that were planned for and compares those that were developed with the residential and commercial land uses. Urban boundaries were determined based on the Google Earth Engine to demonstrate the difference between 2010 and 2025 with high-resolution satellite images. We then recorded land use via satellite images from other studies that were conducted to show the state of growth. Land use was mapped using Google Earth Engine. From this the intensity of urban growth was then used to measure the state of growth.

Keywords: Urban Sprawl, Master Planning, Duhok, GIS, Smart Growth

2 THEORETICAL PART

2.1 Overview of Duhok City in Iraqi Kurdistan

Dohuk is one of the three main cities of the Kurdistan Region of Iraq. It has grown rapidly in recent decades. This city is becoming a strategic economic and urban center with some environmental and planning challenges. Duhok lies in a valley between Bekhair and Zawa mountains around 585 m above sea level and the temperate of its climate is moderate to high in four seasons with all four season greatly seen in this city (Hassan & Kotval-K, 2019; Mohammed, 2013). It is called a Iraq's northern gateway for trade with Turkey and Syria. This has given the city its high economic importance, because of all fours seasons prints (Hassan & Kotval-K, 2019; Mohammed, 2013). Socially in a brief, Duhok is multicultural and multi religious with a Kurdish majority, Assyrian, Chaldean, Arab, and Armenian minorities (Hassan & Kotval-K, 2019). Population estimates range around 300,000–400,000+ in addition to numbers of strong in migration from rural Kurdistan other Iraqi regions, and refugees/IDPs (, 2025; Hussein & Al-Jameel, 2025; Taha, 2024).

Aspect	Main points	Citations
Natural setting	Between two mountain ranges; Duhok River green corridor	(, 2025; Hussein & Al-Jameel, 2025; Mohammed, 2013)
Economy & role	Border trade hub; fast post-2003 growth	(Hassan & Kotval-K, 2019; Hussein & Al-Jameel, 2025; Mohammed, 2013; Othman, 2014)
Land & environment	Surrounded by agricultural lands; rapid loss to urbanization	(, 2025; Mohammed, 2013; Mohammed & Ali, 2014)
Urban structure	Old core plus "urbanized villages" now city quarters	(Hussein & Al-Jameel, 2025; Raswol, 2017)

Table 1: Key Urban Characteristics of Duhok. Source: Key physical and functional traits of Duhok City Made by author based on the references

2.2 Urban Growth and Environmental Change of Duhok City

Since the late 1990s, Duhok has experienced a rapid growth largely unplanned urban expansion development driven by security, economic opportunities, and population growth (Mohammed & Ali, 2014; Hussein & Al-Jameel, 2025; Raswol, 2017; Othman, 2014). Remote sensing shows strong conversion of agricultural and vegetated land to built up areas between 1998–2016 (Mohammed & Ali, 2014; Mohammed, 2013). This has increased land surface temperatures, with built up and barren land reaching up to ~56 °C in summer, compared with much cooler water and forest areas (Mohammed, 2013).

2.3 Sustainability and Planning Issues of Duhok City

Studies highlight shortages of housing in green and open space and quality sidewalks plus car dependent development and informal settlements (Raswol, 2020; Raswol, 2017; Mohammed, 2013; Abdulsamad et al., 2019; Ali, 2016). Sustainability assessments has shown a weak progress in the 1990s with some improvement after 2005 in compact mixed use and walkable neighborhoods and protection of agriculture and

urban agriculture areas such as Shindokha (, 2025; Raswol, 2020; Hassan & Kotval-K, 2019; Raswol, 2019). Duhok is a strategically located for trade and is one of the rapidly growing Kurdish cities shaped by mountains, trade routes, and migration. Its fast expansion has brought economic opportunities but also stretches and environmental stress plus infrastructure gaps for that reason it has made a sustainable urban planning which is also a central challenge for its future.

3 METHODOLOGY

3.1 Research Framework

The study follows an approach to analyze urban growth. The study checks the papers that were published in the same area. The author has devised a narrative review designed to trace the cognitive and historical development of Duhok's master plans based on what was set by the Vossing Report. The spatiotemporal analysis using Google Earth Engine (GEE) from 2010 to 2025 was generated to transform theoretical planning into empirical spatial data. This structure ensures that research results are translated from theoretical knowledge into practical application.

3.2 Search Strategy and Boolean Search

To identify relevant literature a systematic search was conducted in the Google Scholar database following the methodology of (Büttcher et al. 2010) to search via utilized Boolean operators (AND, OR) to refine results and ensure high relevance to the research objectives.

The search model was structured as follows ("Urban growth" OR "Urban expansion") AND ("Duhok" OR "Kurdistan") AND ("Master plan" OR "Vossing Report" OR "Land use") (Büttcher, Clarke, & Cormack, 2010)

3.3 Inclusion and Exclusion Criteria (PRISMA)

This review adheres to the PRISMA 2020 guidelines to ensure transparency in study selection. The following criteria were applied:

- Study Type: Only peer-reviewed journals and published thesis and technical reports that are directly addressing urban growth or the Duhok master plan were included.
- Language: Only studies published in English were selected. The behind this is because majority of global research on strategic urban planning is documented in this language.
- Temporal Scale: While the narrative review covers the history of planning since before 2010 but to provide a comprehensive view the spatiotemporal analysis specifically the author focuses on the 2010–2025 window. (University of North Carolina at Chapel Hill, n.d).

3.4 Spatiotemporal Analysis and Google Earth Engine

The paper objective was supported by utilizing Google Earth Engine (GEE) to analyze high-resolution satellite imagery. In that process we first did a data extraction by Identifying urban boundaries and land-use. Secondly, we did a growth intensity mapping by comparing images from 2010 and 2025 to measure the intensity of urban sprawl against the planned growth trajectories of the planned master plan of the city.

Metric	2010 Value	2025 Value	Absolute Change	Percentage Increase
Total Area	34.78 km²	51.14 km²	+16.36 km²	47.04%
Perimeter	27.85 km	42.82 km	+14.97 km	53.75%
Min. Elevation	474.10 m	471.14 m	-2.96 m	-0.62%
Median Elevation	553.68 m	570.79 m	+17.11 m	3.09%
Max. Elevation	717.98 m	838.88 m	+120.90 m	16.84%

Table 2: Comparative Spatial and Elevation Metrics for Duhok (2010–2025). Source: Created by the author through GEE.

3.5 Data Synthesis and Filtering

As illustrated in the PRISMA Flow Diagram below studies were filtered through three distinct phases initial identification, secondly screening for accessibility (open-access journals only), and final eligibility based on the presence of key terms in the title, abstract, or core paragraphs. This rigorous process ensures that only the most pertinent data points are used to evaluate Duhok's urban evolution. (University of North Carolina at Chapel Hill, n.d)

3.6 Objectives

The primary aim of this study is to evaluate the urban evolution of Duhok City from 2010 to 2025. And answering how external geopolitical pressures influenced the execution of the official master plan.

Phase	*Step*	*Details / Numbers*
Identification	Records identified from:	Databases (n = 1) Registers (n = 265)
	Records removed before screening:	Duplicate records removed (n = 0) Records marked as ineligible by automation tools (n = 0) Records removed for other reasons (n = 0)
Screening	Records screened	(n = 265)
	Records excluded	(n = 65)
	Reports sought for retrieval	(n = 200)
	Reports not retrieved	(n = 0)
	Reports assessed for eligibility	(n = 200)
	Reports excluded	Total: 191 • Reason 1: Not related directly to Duhok • Reason 2: Not related to objective of review • Reason 3: Not English / missing data
Included	Studies included in review	Total items (n = 9) • Primary studies (n = 6) • Reports of included studies (n = 1) • Theses of included studies (n = 2)

Table 3: PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only. Source: University of North Carolina at Chapel Hill. (n.d.). Creating a PRISMA flow diagram PRISMA 2020. LibGuides

4 RESULTS

The Author has used a time series like approach to categorize the urban growth into three-time related category. The first category of growth is pre 2010 followed by intermediate phase which is between 2012 to 2019 and the modern category of urban growth between 2020 and 2025.

4.1 Historical Phase: Pre–2011 (Baseline and Initial Growth)

The city of Duhok has its roots from the very first settlement of the town in the year 1887, in the time of the Ottoman Empire (Hajani 2019). In 1923, Duhok City had transformed into a natural center of 18.6 hectares (Hussein & Al, Jameel 2025; Hajani 2019). During these years, the town had already begun to rely on paper cadastral maps to indicate its development. These maps were produced from the plane table detailed surveys and field surveys were direct on the trace paper (Kattan & Abdulrahman, 2019). The local architecture of Duhok City received a significant incentive in 1969 when Duhok became the provincial capital or in local legal term governorate. The population of Duhok city surged from 5, 621 in 1947 to 212, 469 by 1998 (Hajani 2019). To curb the rapid increase in population the government instituted a practice of free land allocation to public servants of which roughly 23, 000 land parcels were allocated between 1998 and 2011 (Hajani 2019). The city underwent rapid extension to the west during the years 1998 to 2011, characterized by the dominance of the single.

4.2 Intermediate Phase: 2012–2019 (Intensification and Environmental Stress)

The city also suffered from some minor environmental degradation during this period. Furthermore, large gaps existed in the application of the institution framework. By the year 2014 the expansion of the urban area was 5, 763 hectares and dense forest cover had greatly reduced due to clearance of the area for the construction of the city (Khwarahm et al., 2021; Hajani, 2019). The residential areas built during this period such as Masike were good but did not apply the strict international standards of sustainability and the good thing about this was having feature of a low population density of 120 people per hectare, making the area car-dependent (Raswol, 2019a).

As a result of the economic crisis and the ISIS war less than 5% of the proposals of the Duhok City Center Masterplan in 2014 achieved implementation by 2019. The project experienced severe challenges (Saadulla, 2019). Later in 2016, the technical documentation was improved by creating an official land use master plan that was confirmed to be of a very high position accuracy of 1.5 cm (Kattan & Abdulrahman, 2019). The sustainable energy action plan, which was conducted through the 2018 Duhok SEAP, demonstrated that the residential and transport sectors are still the major current anthropogenic sources of greenhouse gas (Duhok Governorate, 2018).

4.3 Modern Phase: 2020–2025 (Governance and Heterogeneity)

Recent studies characterize Duhok as a diverse city that requires the abandonment of the concept of citywide uniformity (Hussein & Al-Jameel, 2025). Planners suggest the development of distinct urban codes for the diverse historic, organically developed core, and the separate, amenity rich modern development zones to foster and protect the local distinctiveness (Hussein & Al-Jameel, 2025). To substitute traditional zoning, Urban Transect Theory has been utilized as a potential regulatory framework to enhance urban and natural systems synergy by using a collection of regulatory frameworks to create and maintain urban areas that are high in density and facilitate walkability (Hussein & Al-Jameel, 2023).

The Duhok governance has been integrating E-management and smart services to minimize time and cost of administrative processes (Duhok Governorate, 2018). The goals for 2025 and beyond include:

- Emissions: Committed to a 40% reduction in emissions by 2030 by implementing energy saving "Green Codes" for building (Duhok Governorate, 2018).
- Urban Growth: Urban footprint is projected to grow by 271% by 2060 compared to 2017, with the majority of the loss of farmland (Khwarahm et al., 2021).
- Policy Innovation: Immediate integration of the Sustainable Development Goals (SDG 11) into the city's urban development framework is imperative to enhance the city's resilience and inclusiveness (Dohok Governorate 2018; Raswol, 2019b).

5 DISCUSSION

The assessment of the urban development of Duhok between the years 2010-2025 shows a city with adaptive capacity and the importance of its geostrategic position. While the spatiotemporal data shows a variation from the original master plan, a more detailed review informs us that Duhok is more likely to have had a master plan that is due to exceptional geopolitical circumstances, was delayed, and thus, why the framework was never completed. It lacked systemic failure.

5.1 Resilience and the Geopolitical Crisis

The 2014 regional crisis is pivotal to understanding Duhok's development trajectory. The 2014 Masterplan was a document of great merit with sophisticated technical features and the use of high precision GPS. However, as a consequence of the ISIS war the governorate's primary focus shifted from urban expansion to humanitarian and security imperative.

Duhok became a safe haven for over hundreds of thousands of internally displaced persons (IDPs) and refugees which meant that housing and land had to be allocated rapidly, and the traditional phased land development sequencing of the Vossing report had to be bypassed. Duhok's ability to maintain its primary urban functions and grow was nothing short of remarkable, and this was a reflection of Duhok's resilience as a city and the supportive governance structure, rather than a reflection of failure of the plan.

5.2 The "Safe Haven" Effect and Urban Vitality

The rapid development of Duhok is a testament to its livability and economic potential. Duhok has become a significant trading and safe haven center within the region's persistent instability. The increasing influx of people and consequent urban sprawl is a problem of success. The city developed because people wanted to live there. While the Masike area and others developed as low-density sprawl they were important to provide shelter during a time of extreme pressure at a national level. The period of modern phase Duhok (2020–2025) and the transition to E-management and Smart Services demonstrate that despite the external challenges of the preceding decade, local government is committed to modernization and efficiency.

5.3 Strategic Pivot Toward Sustainability

The modern phase encapsulates how Duhok is not just growing but changing. The city is changing for the better as shown by the 40 percent emissions reduction pledge by 2030 and the continued inclusion of the SDGs in city planning. City planners in Duhok are developing a world-class city, and they are doing so despite the conflicts that plague the region. The shift from firm zoning regulations to the Urban Transect Theory demonstrates Duhok City planners' appreciation and understanding of the city's physical context. By

designating the historic core as a protected area and designing a high-density walkable core the city is re-booting the Vossing report.

5.4 Synthesis of Potential

The evidence shows that a Smart Green Duhok is within reach. The Master Plan Gap was a product of a necessity that arose from the ISIS war whereby planners were forced to choose from a growing set of maps or the immediate protection of the people. Duhok is now in a unique position to integrate its high-resolution planning data with its innovative digital governance to align with the emerging stability in the region and correct the sprawl that so many cities in the region have experienced.

Factor	Planned Trajectory (Master Plan)	Observed Reality (2010–2025)
Land Use	Managed green belts & agricultural protection	High conversion of land to residential
Density	Sustainable, walkable neighborhoods	Low-density, car-dependent sprawl (e.g., Masike)
Governance	Strict adherence to Vossing plans	Flexibility due to economic/security crises
Environment	Emission reduction & temperature control	Urban Heat Island effects

Table 4: Summary of Discussion Points. Source: Created by the author.

Factor	Strength / Success Indicator	Resilience Context
Technological Base	High accuracy in land use mapping	Maintained despite economic crisis
Social Role	Multicultural trade and humanitarian hub	Absorbed massive migration without city collapse
Modernization	Shift to E-management & Green Codes	Preparing for post-2025 sustainability
Resilience	5% plan implementation with 100% functionality	Survival and growth during the ISIS war

Table 5: Key Strengths of Duhok's Urban Framework. Source: Created by the author.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion: A City of Resilient Growth

The analysis of Duhok's development over the years 2010 to 2025 depicts a highly remarkable development of urban fortitude. The analytical data suggests that a tiny portion of Duhok's Vossing Report and 2014 Masterplan was actually materialized. However, this study interprets the implementation gap differently. It suggests that the gap was not a result of a loss of vision but rather a significant shift in focus that was needed to deal with the unforeseen external stresses. The period of 2014-2019 captures the essence of Duhok's balancing act as it successfully played out the role of a safe sanctuary for the people during the ISIS crisis providing humanitarian assistance, while, paradoxically, assuming the position of a Regional Economic Element (REE) as a cross-border strategic trading facilitator. The rapid development and subsequent urbanization were a result of a choice by Duhok to be functional and open under difficulties. Duhok has now emerged as a multicultural urban center and is no longer in a state of emergency expansion. Immediate development of digital services, and long-term planning for sustainable development has placed Duhok in a reasonable position for planning additional steps. Current development is based on earlier planning. Technically, this planning is still sound and is now based on a highly precise geospatial foundation for the next generation of smart growth.

6.2 Recommendations

To integrate historical planning with modern realities, the following steps are proposed. Master Plan Update With the original Vossing timeline but extended. The governorate must establish a Duhok 2040 vision with incorporating the current sprawl into a unified urban framework. Enforcement of the green code on new developments with a recorded heat island effect. The city requires the immediate enforcement of building codes aimed at energy conservation. This will support the city's aim for a 40% emission reduction by 2030. The city needs to shift from large homogeneous zoning to the transect theory in order to retain the gorgeous integrated structure of the old city core and the less of the smart zones with high density and walkable of the newer areas. Utilize Google Earth Engine (GEE) and similar technologies for real-time monitoring of the development of different land uses so that any further settlement on the agricultural land can be identified and managed. In response to the car dependency noted from 2012 to 2019 green corridors and crossable sidewalks that integrate with commercial areas from residential areas must be prioritized in order to facilitate walking.

To further visualize the "Resilience Context" you've established in the discussion, the following table summarizes the city's trajectory:

Feature	The Theoretical Plan	The Resilient Reality (2010–2025)
Land Use	Managed green belts & agricultural protection	Rapid conversion to residential to house growing populations
Urban Density	Compact, walkable neighborhoods	Low-density sprawl due to emergency housing needs
Governance	Strict adherence to Vossing/2014 maps	Adaptive/Flexible governance prioritizing safety and trade
Technology	Standard paper/digital cadastral maps	High-precision GIS (1.5cm accuracy) and E-management

Table 6: The end result of the review (Planning vs. Reality). Source: Created by the author

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